Ricardian Trade Theory

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Abstract: Ricardian Trade Theory takes cross-country technology differences as the basis of trade. By abstracting from the roles of factor endowment and factor intensity differences, which are the primary concerns of Factor Proportions Theory, Ricardian Trade Theory offers a simple and yet powerful framework within which to examine the effects of country sizes, of technology changes and transfers, and of income distributions. Moreover, its simple production structure makes it relatively easy to allow for many goods and many countries, hence capable of generating valuable insights, which are lost in the standard two-country, two-sector model of international trade.

Ricardian Trade Theory takes cross-country technology differences as the basis of trade. By abstracting from the roles of cross-country factor endowment differences and cross-industry factor intensity differences, which are the primary concerns of Factor Proportions Theory (such as Heckscher-Ohlin and Specific Factor models), Ricardian Trade Theory offers a simple and yet powerful framework within which to address many positive and normative issues of international trade. It is particularly well-equipped to examine the effects of country sizes, of technology changes and transfers, and income distributions. Furthermore, its simple production structure makes it relatively easy to allow for many tradeable goods and many countries, hence capable of generating valuable insights, which are lost in the standard two-country, two-goods model of international trade.

Let us start with the Ricardian model with a continuum of tradeable goods, adopted from Dornbusch, Fischer, and Samuelson (DFS) (1977). The world consists of two countries, Home and Foreign. There is a continuum of competitive industries, indexed by $z \in [0,1]$, each producing a homogenous tradeable good, also indexed by z. There is only one nontradeable factor of production, called labor. (Or, if there are many nontradeable factors, they can be aggregated into a single composite factor.) Let $a(z)$ and $a^*(z)$ be the Home and Foreign unit labor requirements of good z, i.e., labor input required to produce one unit of output z at Home and Foreign. Without loss of generality, we can index z so that Home's relative efficiency, $A(z)$

$\equiv a*(z)/a(z)$, is non-increasing in z. In Figure 1, it is strictly decreasing. In short, Home (Foreign) has **comparative advantage** in low-indexed (high-indexed) goods.

Let w and $w*$ denote the wage rates at Home and Foreign. Then, the prices in autarky are given by $p(z) = wa(z)$ at Home and $p*(z) = w*a*(z)$ at Foreign. Under free trade (and in the absence of any trade costs), the price of each good is equalized across the two countries and is given by $p(z) = p*(z) = \min\{wa(z), w*a*(z)\}$. Then, for a given relative wage rate or a given level of the **factoral terms of trade**, $w/w*$, there is a marginal good, m, defined by

(1) $\qquad \dfrac{w}{w*} = A(m)$,

such that Home produces only goods in $[0,m]$, and Foreign produces only goods in $[m,1]$, and the prices become

(2) $\qquad p(z) = p*(z) = wa(z), \; z \in [0,m]; \qquad p(z) = p*(z) = w*a*(z), z \in [m,1]$.

To pin down the relative wage rate, we must specify the demand conditions. To keep it simple, let us assume that there are L ($L*$) households at Home (Foreign), each supplying one unit of labor, and that every household shares the symmetric Cobb-Douglas preferences defined over $z \in [0,1]$, as $U = \int_0^1 \log[c(z)]dz$ and $U* = \int_0^1 \log[c*(z)]dz$. Then, the world income (and the world total expenditure), $wL+w*L*$, is also equal to the world expenditure on each good. Since Home produces the goods in $[0,m]$, the total expenditure on the Home goods is $m(wL + w*L*)$, which must be equal to the Home income, wL, in equilibrium. This condition yields

(3) $\qquad \dfrac{w}{w*} = \dfrac{m}{1-m}\left[\dfrac{L*}{L}\right]$

which is depicted by the upward sloping curve in Figure 1. It is upward-sloping because a higher m means that a larger fraction of the world expenditure goes to the goods produced by the Home labor, hence its relative wage goes up. As shown by the intersection of the two curves in Figure 1, eq. (1) and eq. (3) jointly determine the equilibrium relative wage rate, $w/w*$, and the equilibrium patterns of trade and specialization, m, as Home exports and Foreign imports goods in $[0,m)$ and Home imports and Foreign exports goods in $(m,1]$. In short, **the patterns of trade follow the patterns of comparative advantage.**

The standard two-country, two-goods Ricardian model, found in many college textbooks, may be recovered as a special case of this model, where $A(z) = A_1$ for $z \in [0, \alpha]$ and $A(z) = A_2$ for $z \in (\alpha, 1]$, with $A_1 > A_2$, as shown in Figure 2. By aggregating all the goods in $[0, \alpha]$ as a

composite good, called Good 1, and all the goods in $(\alpha, 1]$ as another composite good, called Good 2, the model becomes a two-sector model, where the households have the preferences, $U = \alpha\log(C_1) + (1-\alpha)\log(C_2)$ and $U^* = \alpha\log(C^*_1) + (1-\alpha)\log(C^*_2)$. Viewed this way, the model highlights the restrictive feature of the two-good assumption in the textbook Ricardian model.

Gains from Trade and Country Size Effects:

The Home and Foreign welfares are measured by $U = \int_0^1 \log[w/p(z)]dz$ and $U^* = \int_0^1 \log[w^*/p^*(z)]dz$, respectively. In autarky, they are equal to

(4) $U_A = -\int_0^1 \log[a(z)]dz$; $U_A^* = -\int_0^1 \log[a^*(z)]dz$;

and, under free trade, they are equal to

(5) $U_T = -\int_0^m \log[a(z)]\,dz + \int_m^1 \log\left[\dfrac{w}{w^* a^*(z)}\right]dz$; $U_T^* = \int_0^m \log\left[\dfrac{w^*}{wa(z)}\right]dz - \int_m^1 \log[a^*(z)]dz$;

Subtracting (4) from (5) and using (1) show that the welfare changes from autarky to free trade by:

(6) $\Delta U = U_T - U_A = \int_m^1 \log\left[\dfrac{A(m)}{A(z)}\right]dz$; $\Delta U^* = U_T^* - U_A^* = \int_0^m \log\left[\dfrac{A(z)}{A(m)}\right]dz$,

both of which are strictly positive in the case depicted in Figure 1. More generally, both countries gain from trade, as long as $0 < m < 1$ and $A(0) > A(m) > A(1)$. Note that this condition could hold even when one country, say Home, has **absolute advantage** over the other, say Foreign, that is, $A(z) > 1$ for $z \in [0,1]$. Clearly, such absolute advantage allows Home households to enjoy higher wage income and hence higher standard-of-living than Foreign households, $w > w^*$, and $U_T - U_T^* = \log(w) - \log(w^*) > 0$. Yet, both countries gain from trade as long as trade allows them to specialize in the goods that they are relatively good at producing.

In the two-goods case, shown in Figure 2, both countries gain from trade only when $m = \alpha$ and $A_1 > w/w^* > A_2$, which requires that $A_2(1-\alpha)/\alpha < L^*/L < A_1(1-\alpha)/\alpha$. Home does not gain from trade if $w/w^* = A_2$, which occurs when $L^*/L \leq A_2(1-\alpha)/\alpha$, and Foreign does not gain from trade if $w/w^* = A_1$, which occurs when $L^*/L \geq A_1(1-\alpha)/\alpha$. This result of the two-sector model is often interpreted as saying that a large country cannot gain from trade, as it remains *incompletely* specialized, or that a country must *fully* specialize in order to gain from trade, but this is due to

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an artificial feature of the two-goods model which restricts the cross-country differences in technology.

What is generally true is that, as one country becomes large (small) relative to the rest of the world, its gains from trade become smaller (large). As shown in Figure 1, an increase in L^*/L, which shifts the upward-sloping curve to the left, leads to a higher w/w^* and a lower m, which implies a higher ΔU and a lower ΔU^*, as seen from (6). For example, a faster population growth in the South (Foreign) allows the North (Home) to specialize further, which improves its factoral terms of trade and its standard of living at the expense of the South. (The same phenomenon might be described by the protectionist in the North as "because of the cheap labor in the South, the North loses its competitive advantage and industries move from the North to the South.)

This also suggests that a country with a small population size could enjoy higher per capita income even with limited technological superiority. In Figure 3, Home's technologies are inferior in almost all the goods, yet, thanks to its relatively small population size, Home enjoys higher per capita income. This may explain why countries like Norway and Switzerland enjoy a high standard of living despite that the geography and climates are not particularly suitable to most economic activities. With the smaller population sizes, they can maintain a high standard of living by specializing in a narrower range of activities that they are particularly good at. This effect is difficult to see within a two-goods model.

These results suggest diminishing returns to scale (DRS) at the country level, even though technologies satisfy the constant returns to scale (CRS) property. This is because the endogeneity of the terms of trade, w/w^*, introduces *de facto* diminishing returns. To see some macroeconomic implications, let us reinterpret the model in the following way. Home and Foreign produce their GDPs, Y and Y^*, by the CRS aggregate production function, $\log(Y) = \int_0^1 \log[c(z)]dz$ and $\log(Y^*) = \int_0^1 \log[c^*(z)]dz$, where $c(z)$ and $c^*(z)$ denote the inputs of the tradeable intermediate goods, $z \in [0,1]$. The representative household at Home and at Foreign supplies L and L^* units of the composite of the primary factors, which may include not only labor but also physical and human capital. Then, the expressions analogous to (5) become

$$\log\left[\frac{Y}{L}\right] = \int_m^1 \log\left[\frac{w}{w^* a^*(z)}\right]dz - \int_0^m \log[a(z)]\,dz;$$

$$\log\left[\frac{Y*}{L*}\right] = \int_0^m \log\left[\frac{w*}{wa(z)}\right]dz - \int_m^1 \log[a*(z)]dz .$$

The effect of a change in L and $L*$ can be seen by totally differentiating the above expressions, which yields the following growth accounting;

$$\frac{dY}{Y} = \frac{dL}{L} + (1-m)\left[\frac{dw}{w} - \frac{dw*}{w*}\right]; \qquad \frac{dY*}{Y*} = \frac{dL*}{L*} + m\left[\frac{dw*}{w*} - \frac{dw}{w}\right].$$

If L and $L*$ grow at the same rate, $w/w*$ remains constant, and hence both Y and $Y*$ also grow at the same rate. However, if L grows faster than $L*$, then Y grows slower than L and $Y*$ grows faster than $L*$ through the terms of trade effect. This example also suggests that, even when there are increasing returns to scale (IRS) in the aggregate production technologies, naïve cross-country growth regression exercises which do not take into account interdependence among countries might fail to uncover economies of scale. See also Acemoglu and Ventura (2002), which studies how such a terms-of-trade mechanism generates stable cross-country distribution of income in the world even when different countries accumulate factors at different rates.

Technology Changes and Transfers:

Because it takes cross-country technology differences as the basis of trade, the Ricardian model is well-suited to study the effects of technology changes. Let $g(z) \equiv - \text{dlog}[a(z)]$ and $g*(z) \equiv - \text{dlog}[a*(z)]$ denote the rate of productivity change in industry z at Home and Foreign. By totally differentiating (5), the Home welfare changes can be expressed as

$$dU = \int_0^m g(z)dz + \int_m^1 g*(z)dz + \left[\frac{1-m}{1 + \xi(m)m(1-m)}\right][g(m) - g*(m)]$$

where $\xi(z) \equiv - \text{dlog}[A(z)]/dz$. For example, it is easy to see that Home always gains from productivity growth in its export sectors, $g(z) > 0$ for $z \in [0,m]$. Does Home gain from productivity growth abroad, as well? If Foreign experiences a *uniform* productivity growth in its export sectors (i.e., $g*(z) = g* > 0$ for all $z \in [m, 1]$), then the answer is yes because

$$dU = \left[\frac{m(1-m)^2 \xi(m)}{1 + \xi(m)m(1-m)}\right]g* > 0,$$

unless $\xi(m) = 0$, in which case productivity gains in the Foreign export sectors are entirely offset by the terms of trade change.

On the other hand, Home may lose from Foreign productivity growth if it is concentrated around the marginal sector, m. The following example, taken from Jones (1979), illustrates this possibility. Let $A(z) = A_1 = a_1^*/a_1$ for $z \in [0, \alpha_1]$; $A(z) = A_2 = a_2^*/a_2$ for $z \in (\alpha_1, \alpha_1+\alpha_2]$, and $A(z) = A_3 = a_3^*/a_3$ for $z \in (\alpha_1+\alpha_2, 1]$, with $A_1 > A_2 > A_3$. Again, we may view this example as a three-sector model, by aggregating all the goods within each segment, as Good 1, 2, and 3. When the upward-sloping curve intersects with $A(z)$ at its middle segment, $w/w^* = A_2$. Then, the Home and Foreign welfares are given by

$$U_T = (1-\alpha_1+\alpha_2)\log(a_2^*/a_3^*); \qquad U_T^* = -(\alpha_1+\alpha_2)\log(a_2^*) - (1-\alpha_1+\alpha_2)\log(a_3^*),$$

where we normalize $a_1 = a_2 = a_3 = 1$ without loss of generality to simplify the expression. The Home welfare declines (and the Foreign welfare improves) unambiguously when Foreign productivity growth takes the form of a reduction in a_2^*, depicted by the arrow in Figure 4. The reason for the Home loss is that the Home purchasing power measured in Good 2 remains unchanged as Foreign productivity growth is completely offset by the increase in the Foreign wage, while the Home purchasing power measured in Good 3 declines, as the increase in the Foreign wage makes it more expensive.

The above example again demonstrates the restrictiveness of the two-goods assumption. In particular, it suggests that the widely used distinction between "export-biased" and "import-biased" technology changes in two-sector models, first introduced by Hicks (1953), is of very limited value, as they can be applied only when these changes are uniform across all the export (or import) sectors. Indeed, it can be misleading because the effects of technology changes that take place in *some* export sectors may be very different from those of "export-biased technological changes" in the two-sector model. (A similar point can be made for the analysis of trade policies. In the standard competitive two-sector model of trade, the government cannot improve its national welfare by providing export subsides to its export sector. This should be interpreted as saying that export subsidies provided *uniformly* to all of its export sectors cannot improve its national welfare. Indeed, using the Ricardian models similar to the one above, Itoh and Kiyono (1987) showed that *selective* export subsidies that *target* sectors around the marginal sector, can improve the national welfare.)

The same mechanism could operate when the technologically lagging country succeeds in catching up with the technologically leading country. Suppose $a(z) = 1$ for all $z \in [0,1]$ and $A(z) = a^*(z) = \Lambda^{1-z}$, where $\Lambda > 1$ is a parameter, representing the extent to which Foreign "lags

behind" Home technologically. For example, each tradeable good is produced by performing two tasks by x_1 and x_2, with the Cobb-Douglas production function, $F^z(x_1, x_2) = [x_1/z]^z[x_2/(1-z)]^{1-z}$, and that the unit labor requirement for task 1 is equal to one everywhere, while the unit labor requirement for task 2 is one at Home and $\Lambda > 1$ at Foreign. One may think that Λ reflects the technology gap, which affects when performing task 2, but not task 1. Then, Home has absolute advantage in all the goods, but Foreign has comparative advantage in the high-indexed goods, which can be produced mostly by performing the simple task 1. (Krugman (1986) offered another story behind a similar parameterization of $A(z)$.) With this parameterization, we have

$$U_T = \frac{(1-m)^2}{2}\log\Lambda, \ \ U_T^* = -\frac{1-m^2}{2}\log\Lambda,$$

where m is determined by the condition, $mL^*/(1-m)L = \Lambda^{1-m}$. Home could lose if Foreign succeeds in narrowing the gap (i.e., a reduction in Λ). The reason is easy to understand. As the gap narrows, Foreign becomes more similar to Home, and Home gains little from trading with a country similar to itself. Indeed, if Foreign catches up completely, $\Lambda = 1$, Home loses all the gains from trading with Foreign because the two countries become identical. Note that the underlying mechanism in this example is the same as in the three-goods example. When Foreign narrows the gap, their productivity growth is not uniform across its export sectors. It is larger in the sectors in which Home has bigger absolute advantages. However, it is false to say that Home suffers because Foreign productivity growth is "import-biased." The Home loss is caused by Foreign productivity growth around the marginal sector, not at the lower end of the spectrum.

Nontraded Goods, Trade Costs, and Effects of Globalization

We have been examining the effects of trade by comparing the two extreme cases: Autarky, where no goods are traded, and "Free" Trade, where all goods are costlessly tradeable. Let us now introduce some trade costs and examine the effects of (partial) trade liberalization by reducing the trade costs. Matsuyama (2007c) conducts such exercises by following DFS (1977), which proposed two alternative ways of introducing trade costs in their model: Traded versus Nontraded Dichotomy and Uniform Iceberg Cost.

Traded versus Nontraded Dichotomy: Suppose that only the goods in [0,k] are tradeable at zero cost and $A(z) \equiv a^*(z)/a(z)$ is continuous, and strictly decreasing in z, within this range. On

the other hand, trade costs are so high for the goods in (k, 1] that they need to be produced locally. At this point, we do not have to specify the production technologies for these nontradeables.

Given the marginal good, $m \in [0,k]$, defined by $A(m) = w/w^*$, Home produces all the goods in $[0,m]$ for both countries and Foreign produces all the goods in $(m, k]$. In addition, each country produces all the goods in $(k,1]$ locally. Therefore, the total expenditure on the goods produced at Home is equal to $m(wL+w^*L^*)+(1-k)wL$, which must be equal to the Home income, wL, in equilibrium. This condition yields

(7) $$\frac{w}{w^*} = \frac{m}{k-m}\left[\frac{L^*}{L}\right].$$

The equilibrium is determined jointly by Eq. (1) and Eq. (7), as shown in Figure 5. DFS (1977) used this extension to study the classical transfer problem. In the presence of the nontraded goods, the German households spend a large share of their income on the goods produced in Germany than the households abroad. Because of this "home-bias" in demand, an exogenous income transfer from Germany to the Allies (the war reparations after the Treaty of Versailles) shifts the demand away from the German goods, which leads to a deterioration of the German terms of trade, imposing the additional burden on the German economy.

Let us use this model to study the effects of a globalization. Imagine that some nontradeables become tradeable. For example, the governments might decide to lift the bans on trading some goods that can be traded costlessly. Or, advances in information and communication technologies might open up the possibility of trading some labor services at zero cost. The effects, of course, depend on the relative efficiency of the two countries on producing these newly tradeables. Let us consider the case where $A(z) = A$ for all $z \in (k,1]$, and that a fraction g of these goods becomes newly tradeable at zero cost. Then, if $w/w^* > A$, all of the newly tradeables are produced at Foreign. Therefore, given the marginal good, $m \in [0, k]$, Home produces all the goods in $[0, m]$ for both countries and $(1-g)(1-k)$ fraction of the goods (those which remain nontradeable) locally. Hence, in equilibrium, $wL = m(wL+w^*L^*) + (1-g)(1-k)wL$. On the other hand, if $w/w^* < A$, all of the newly tradeables are produced at Home. Therefore, Home produces $m+g(1-k)$ fraction of the goods for both countries and $(1-g)(1-k)$ fraction of the goods locally. Hence, in equilibrium, $wL = [m+g(1-k)](wL+w^*L^*) + (1-g)(1-k)wL$. Thus, we have, instead of (7),

(8) $\dfrac{w}{w^*} = \dfrac{m+g(1-k)}{k-m}\left[\dfrac{L^*}{L}\right]$ for $\dfrac{w}{w^*} < A$; $\dfrac{w}{w^*} = \dfrac{m}{k+g(1-k)-m}\left[\dfrac{L^*}{L}\right]$ for $\dfrac{w}{w^*} > A$;

and $w/w^* = A$, otherwise. Note that setting $g = 0$ in eq.(8) recovers eq.(7). A higher g shifts the graph to the right above $w/w^* = A$ and to the left below $w/w^* = A$. For each value of g, eq.(1) and eq.(8) jointly determines the marginal good and the Home relative wage, which we denote by $m(g)$ and $A(m(g))$.

Suppose that, before globalization, $g = 0$, the equilibrium Home relative wage, $A(m(0))$, is higher than A, as shown in Figure 5.   The arrow indicates the shift caused by an increase in g, which is small enough to keep the Home relative wage higher than A. When some nontraded sectors are opened up, Home abandons the production of these new tradeables, and instead start producing and exporting the goods in $(m(0), m(g)]$, which Home imported previously. The Home relative wage declines as a result, from $A(m(0))$ to $A(m(g))$. The Home and Foreign welfares may be evaluated by

$$U(g) = \int_{m(g)}^{k} \log\left[\frac{A(m(g))}{A(z)}\right]dz + g(1-k)\log\left[\frac{A(m(g))}{A}\right];$$

$$U^*(g) = m(g)\log\left[\frac{A}{A(m(g))}\right] + \int_{m(g)}^{k} \log\frac{A}{A(z)}dz - \log A,$$

where we use the normalization, $A(z) = a^*(z)/a(z) = a^*(z)$ for all $z \in [0,1]$, to simplify the expressions. A globalization (an increase in g) affects the Home welfare through two effects that operate in the opposite directions. On one hand, it allows Home to reallocate its labor to the sectors where they have higher relative efficiency, that is, from A to $A(m(g))$ or higher. On the other hand, its relative wage rate, or the factoral terms of trade, $w/w^* = A(m(g))$, deteriorates. The overall effect is generally ambiguous. However, if an increase in g brings down its relative wage rate $A(m(g))$ sufficiently close to A, the positive reallocation effect is dominated by the negative terms of trade effect, so that a further globalization harms the Home welfare. In contrast, a globalization unambiguously improves the Foreign welfare, because both effects operate positively.

The possibility that Home could lose when a globalization takes this form should not be too surprising, because it can be viewed as a form of non-uniform technological changes. Indeed, this mechanism may capture some of the widely held concerns that high-wage countries might lose from "outsourcing" simple tasks to low-wage countries.

Uniform Iceberg Cost: Suppose now that all the goods, $z \in [0,1]$, are tradeable but subject to the iceberg cost. Each good, when shipped abroad, melts away in transit and only a fraction $g < 1$ arrives to the destination. Thus, in order to supply one unit of each good, the exporter must produce $1/g > 1$ units of the good. Then, Home exports to Foreign only when $a(z)w/g < a*(z)w*$, or $w/w*g < A(z)$, and Foreign exports to Home only when $a(z)w > a*(z)w*/g$, or $wg/w* > A(z)$. Thus, there are two marginal goods, defined by

$$(9) \qquad \frac{w}{w*g} = A(m^-) > A(m^+) = \frac{wg}{w*}$$

such that Home produces all the goods in $[0, m^-)$ for both countries; Foreign produces all the goods in $(m^+, 1]$ for both countries, and each produces the goods in $[m^-, m^+]$, which becomes (endogenously) nontraded goods. The demand condition now becomes

$$(10) \qquad \frac{w}{w*} = \frac{m^-}{1 - m^+}\left[\frac{L*}{L}\right].$$

Eqs. (9) and (10) jointly determine three endogenous variables, m^-, m^+, and $w/w*$.

One could proceed to examine the effects of a reduction in the trade cost, by increasing g. Unlike the previous case, a globalization of this form always benefits both countries, because it affects all the sectors uniformly.

Multiple Countries

The two-country assumption is clearly restrictive for certain purposes, such as analyzing the income distribution across countries, studying the patterns of bilateral trade flows, let alone the issues related to the regional integration, such as NAFTA. It is relatively straightforward to extend the two-goods Ricardian model for an arbitrary number of countries; see, e.g., Becker (1952) for a finite number of countries and Matsuyama (1996) and Yanagawa (1996) for a continuum of countries. It has been a challenge to allow for an arbitrary number of goods *and* countries in a tractable way. For example, Wilson (1980) extended the DFS model in many dimensions, including a finite number of countries, but it does not permit more than a local perturbation analysis. Acemoglu and Ventura (2002), in their analysis of the cross-country income distribution, assumed the extreme form of technological heterogeneity by adopting the Armington assumption, which prevents the patterns of specialization from changing endogenously.

Eaton and Kortum (2002) recently developed a parsimonious representation of the Ricardian model with a continuum of goods, which allows for an arbitrary number of countries with the iceberg costs that are uniform across sectors but vary across country-pairs. Their key idea is to view the technology heterogeneity across countries as a realization from the Frechet distributions, instead of trying to index the goods in a particular order. This yields simple expressions relating the bilateral trade volumes to technology and geographical barriers, and they use these expressions to estimate the parameters needed to quantify the effects of various policy experiments. For further development, see Alvarez and Lucas (2004).

Multi-Stage Trade and Vertical Specialization

Sanyal (1982) proposed a reinterpretation of the DFS model, according to which the final good is produced through many stages of production, $z \in [0,1]$, in order to analyze trade in intermediate inputs and vertical specialization. If the order in which these inputs need to be produced in the vertical chain of production perfectly coincides with the pattern of comparative advantage, as Sanyal assumed, these inputs are traded only once, as one country specializes in the earlier stages of production and the other specializes in the later stages. Under more general patterns of comparative advantage, however, these inputs may be traded back and forth many times. In such a setting, even a small reduction in trade costs could cause a large and nonlinear increase in the volume of trade, as documented by Hummels, Ishii, and Yi (2001).

More General Preferences:

With the Cobb-Douglas specification, each good receives a constant share of the expenditure regardless of the prices. Its homotheticity implies that the rich and the poor consume all the goods in the same proportions (when they all face the identical prices), so that the demand compositions are independent of the income distribution within each country. These features, while greatly simplifying the analysis, are too restrictive for addressing many important issues related to growth and development.

Consider, for example, the Fisher-Clark-Kuznets thesis, that is, the changing patterns of sectoral compositions, with the decline of agriculture, the rise and the fall of manufacturing, and the rise of the service sectors. To understand such patterns of structural change in the context of a global economy, Matsuyama (2007b) relaxed the Cobb-Douglas assumption to allow for non-

unitary price and non-unitary income elasticities in the three-goods (two tradeable and one nontradeable) Ricardian model.

Non-homothetic preferences also play the key roles in many models of North-South trade. Flam and Helpman (1987), Stokey (1991), and Matsuyama (2000) all built two-country (North and South) Ricardian models with a continuum of goods, with the open-ended goods space, $z \in [0,\infty)$, and considered non-homothetic preferences with the property that, as the household's income goes up, its demand compositions shift towards higher-indexed goods. When the South, the poorer country, has comparative advantages in lower-indexed goods, the demand has home-biases (in spite of the absence of any trade costs). Furthermore, the asymmetry of demand generates many comparative statics results that are absent in the standard Ricardian model. For example, in Matsuyama (2000), immiserizing growth might occur; a uniform productivity growth in the South might make the South worse off, as all the benefits go to the North. Or, as the South's population grows, some industries migrate from the North to the South, and new industries are born in the North, generating the patterns of product cycles. Flam and Helpman (1987) and Matsuyama (2000) also looked at the roles of income distributions within each country by endowing different households with different amounts of labor.

Endogenous Technologies and Increasing Returns

So far, we have taken the cross-country differences in technology as exogenous and examined their effects on patterns of specialization and trade. However, the patterns of trade and specialization may also affect technologies. Many Ricardian models with endogenous technologies have been developed to examine such two-way causality between technology and trade. Endogenous technologies have also been used as a natural way of introducing increasing returns in production. Due to the space constraint, we cannot do justice to this vast literature, which contains many alternative approaches to endogenize technologies (static external economies of scale, dynamic increasing returns due to learning-by-doing with or without inter-industry spillovers, agglomeration economies with endogenous product varieties, R&D activities, etc.) with a wide range of results with different policy implications. The interested reader should start with a survey by Grossman and Helpman (1995).

Beyond Technologies: Policy-Induced and Institution-Based Comparative Advantage

The Ricardian setup has also been used to explain how the differences in national policies and institutions give rise to the patterns of comparative advantage, even in the absence of any inherent technology differences. In Copeland and Taylor (1994), the clean environment is a normal good, so that the rich North chooses a higher pollution tax than the poor South. As a result, the North (South) ends up having comparative advantages in less (more) polluting industries. In Matsuyama (2005), Costinot (2006), and Acemoglu, Antras, and Helpman (2006), industries differ according to the severity of agency or contractual problems, and the country with a better (worse) institutional setup to deal with these problems has comparative advantages in industries that are more (less) subject to these problems. One may view this line of research as an attempt to endogenize technology differences. Unlike the literature surveyed by Grossman and Helpman (1995), however, the main objective here is to look at the deeper or more fundamental causes of technology differences, rather than looking at the two-way causality between technology and trade.

Finally, because the Ricardian trade theory abstracts from the roles of factor endowment differences across countries and factor intensity differences across industries as the basis of trade, it is an ideal setup in which to isolate the roles of factor endowments and intensity differences that are unrelated to the basis of trade. For example, Matsuyama (2007a) used a two-country Ricardian model to examine how the factor intensity affects the extent of globalization and how globalization affects the factor prices when certain factors are used more intensively in international trade than in domestic trade. The model is Ricardian in the sense that the patterns of comparative advantage are determined entirely by the exogenous technological differences. The factor proportions matter, however, because they determine the extent of globalization, as the effective trade costs vary with the relative endowments of the factor used intensively in international trade.

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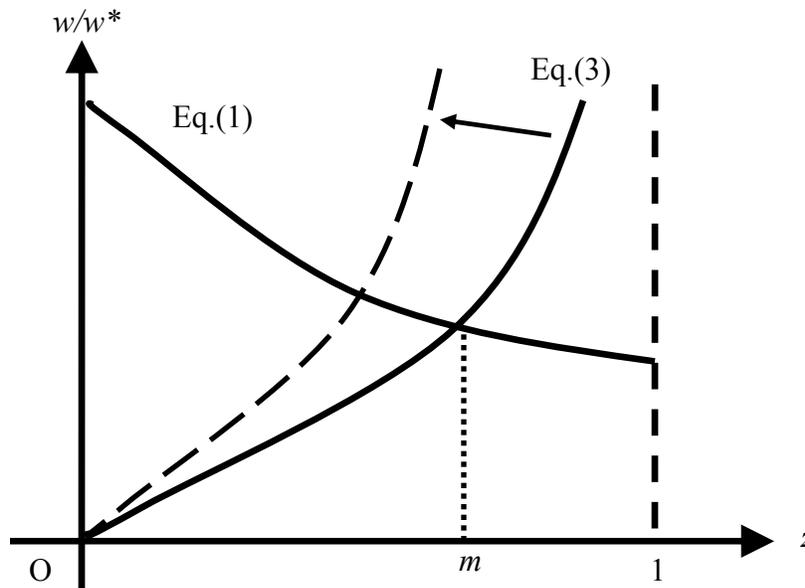Figure 1: The Equilibrium Factor Terms of Trade and Patterns of Specialization
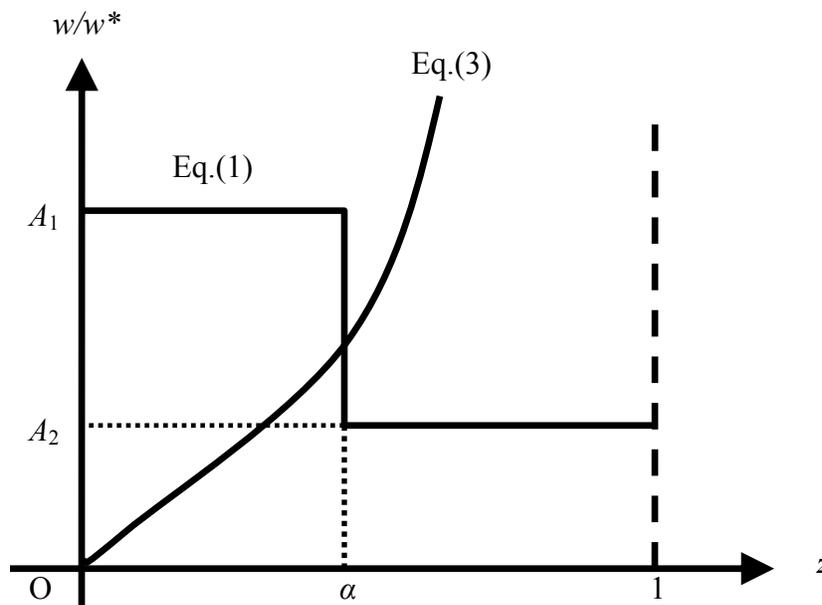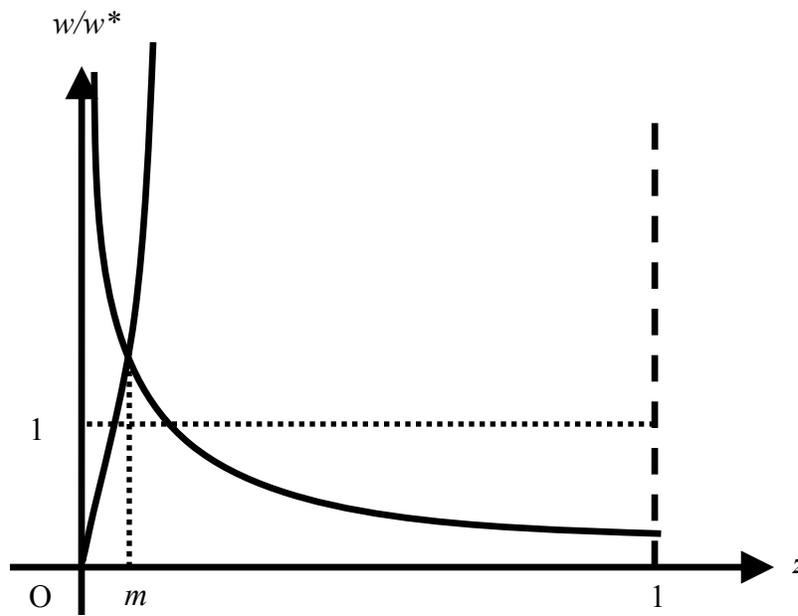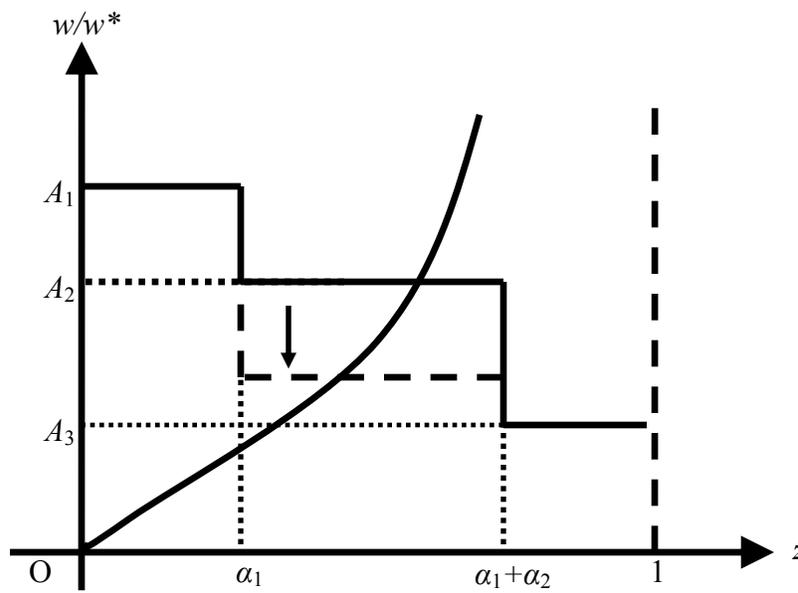

Figure 2: The Two-Goods Case

Figure 3:

Figure 4: The Three-Goods Case

Figure 5: Non-Uniform Globalization